モチーフ構造を活用した
脳型ソフトウェア向け機能階層図の
ボトムアップからの構築

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Whole Brain Architecture Initiative

Data for Brain Reference Architecture of YM24Amygdala

Neural Architecture for Amygdala Fear Conditioning

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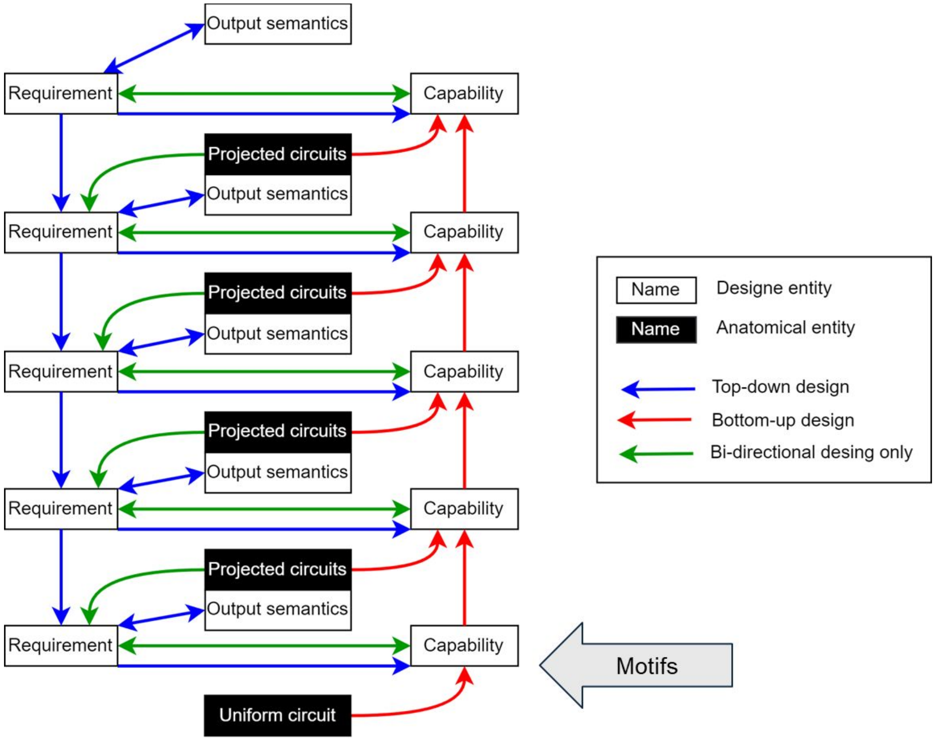
BRA driven depelopment

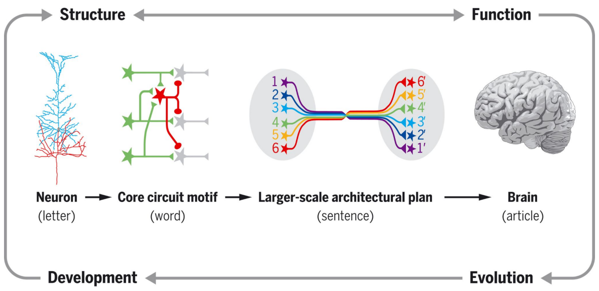


・脳機能を考えるうえで、
トップダウンかボトムアップ、
あるいはその両方から考える方向性がある。

・今回は、ボトムアップからの積み上げによって機能を考える。

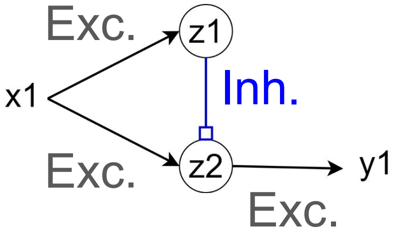
・「モチーフ」という構造に着目する。

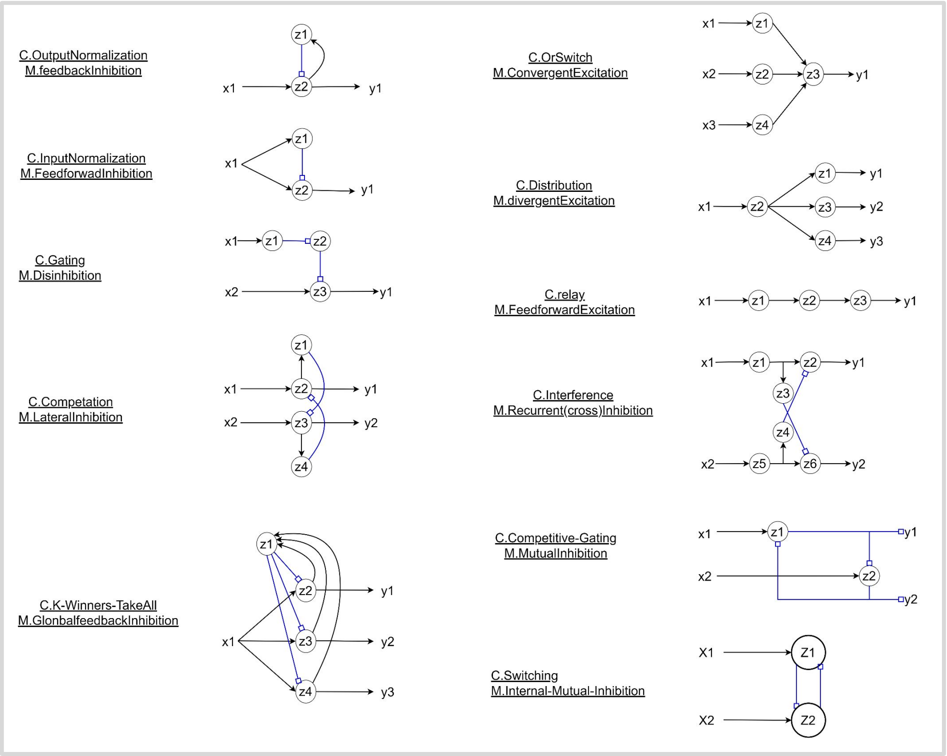
Motifs



(L Luo., 2021, science)

C.InputNormalization
M.FeedforwadInhibition

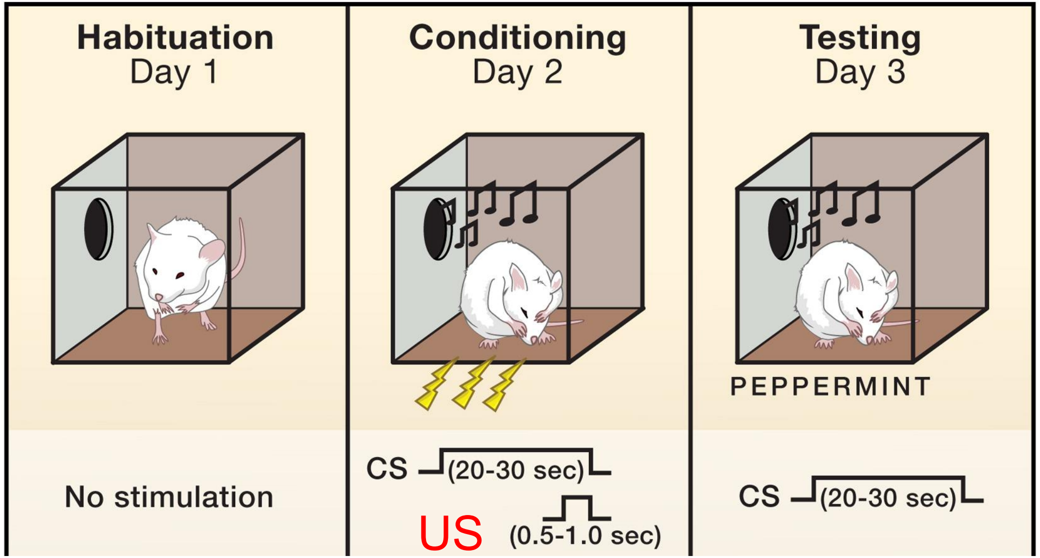




・モチーフは、ニューロン(や神経核)が集まった一つの構造単位で、対応して機能が付与されている。
・例えば、下流の信号強度を調節する、Input-Nomarizationがある。
・これらの構造に対応する機能を組み合わせて、脳のある領域の機能を考えていこうというとする
　概念自体はあるが、実際の取り組みはまだあまりない。

Background of the Data (1/2)

□Amygdala fear conditioning.



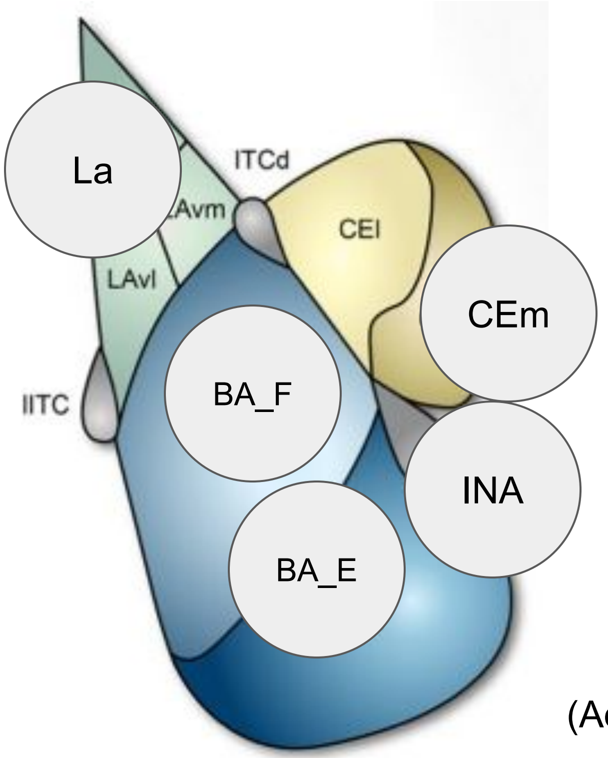
(Joshua P._Johansen et al., 2011)

・今回対象とする、
扁桃体(Amygdala)には
恐怖条件付け回路がある。

・恐怖を引き起こす刺激(US)と
無関係な刺激(CS)を
「対」で提示すると、
無関係な刺激に恐怖反応を
起こす。

Background of the Data (2/2)

□Amygdala fear conditioning circuitry.



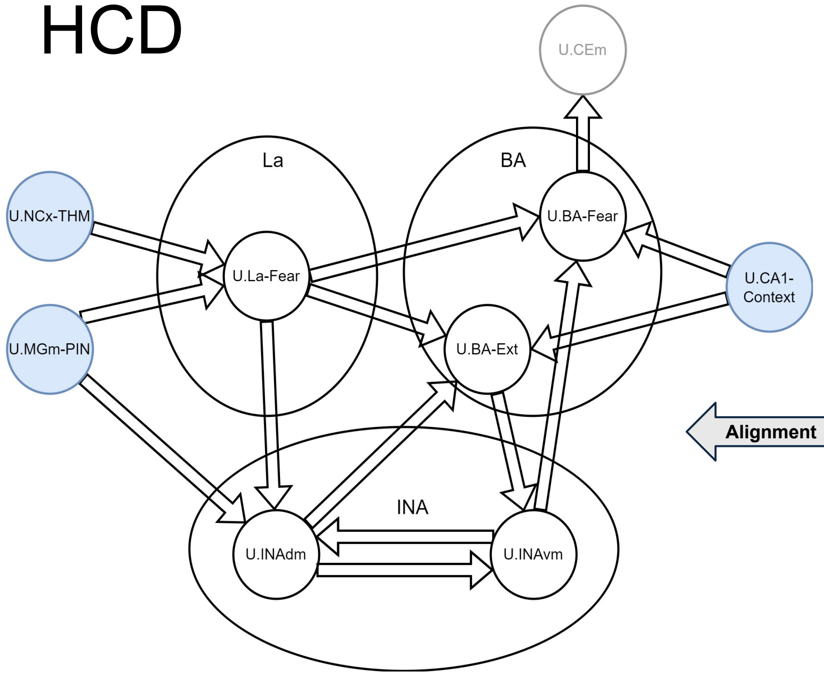
・解剖学的知見等から、この恐怖反応には、
以下の領域が大事。
Lateral nucleus (La),
Basal nucleus (BA),
Central nucleus (CEN), and
Intercalated cell masses (INA)

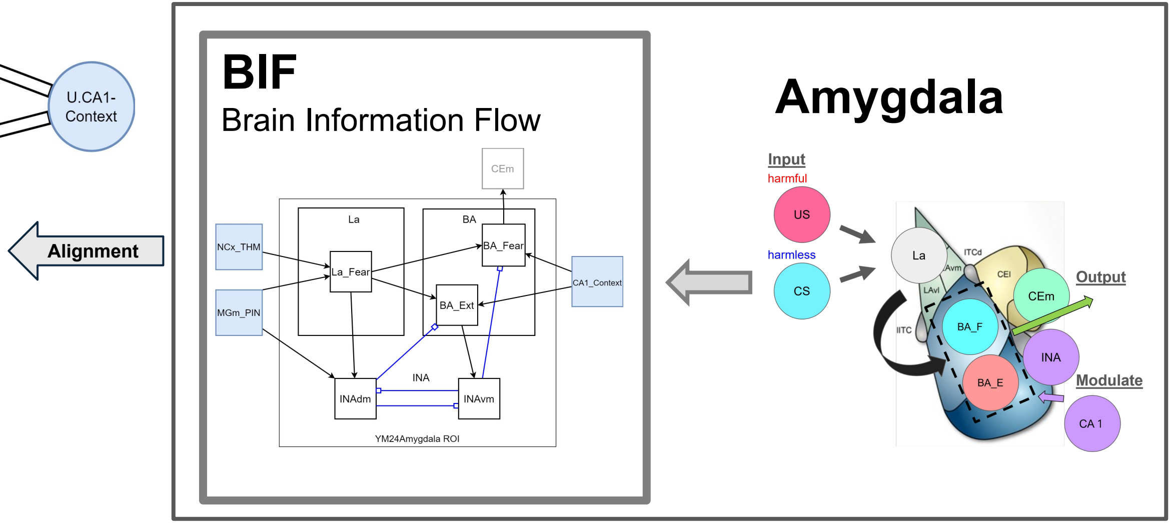
・これらの領域に着目して、HCDを形成し、
motifをあてこんでいって、ボトムアップで
機能を考える。

(Adapted from Seungho Lee et al., 2013.)

HCD and FRG

HCD



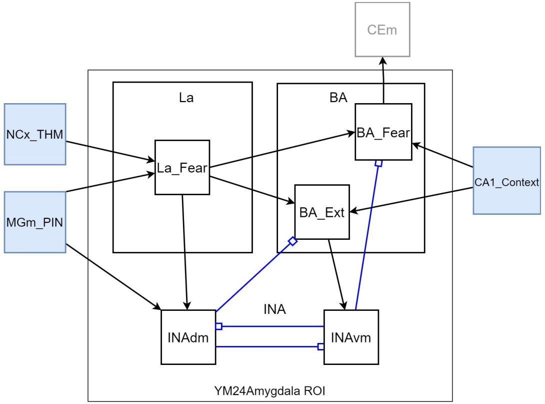


・仮説的コンポーネント図であるHCDは、解剖学的知見の集合であるBIFをもとに構築。
HCDとBIFともにTM24 Amygdala projectで構築。

・HCDにmotifを当て込んで、Amygdalaの機能がmotifの機能の積み上げで表現できそうか見ていく。

BIF data (neural nuclei)

BIF



- BIFとHCDは**TM24Amygdala** project にて構築されている。
- BIFは8つの神経核と、14のコネクションから成る。

Circuits(neural nuclei, 8)

	A	B	C	D	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
1	Circuit ID	Source of ID	Names	DHBA: graph_order	Sub-Circuits	Super Class	Uniform	Trans mitter	Modul ation Type	Size	Output Semantics (0)	Physiological Data	Comments	Contributor	Project ID	WBIF pull request	WBIF copied	Review results	Auto Error Codes
2	YM24Amygdala	[Maruyama, 2024]	ROI of YM24Amygdala	1760.1	La_Fear;BA;INAdm;IN Avm;		FALSE							Yoshimasa Tawatsuji	TM24Amygdala			0	
3	NCx_THM	makeshift	Conditioned stimulus of fear conditioning	1760.1	NCx; THM;		TRUE		Excitat ory					Tatsuya Miyamoto	TM24Amygdala			Warning: 1	1 Warning(s); [109:Source of ID]
4	MGm_PIN	[Asede, 2022]	Unconditioned stimulus of fear conditioning	1760.1			TRUE		Excitat ory					Tatsuya Miyamoto	TM24Amygdala			0	
5	BA	[Duvarci, 2014]	Basal nucleus of Amygdala	1793.2	BA_Fear;BA_Ext;		FALSE							Tatsuya Miyamoto	TM24Amygdala			0	
6	BA_Fear	makeshift	Fear cell of BA	1793.2			TRUE		Excitat ory					Tatsuya Miyamoto	TM24Amygdala			Warning: 1	1 Warning(s); [109:Source of ID]
7	BA_Ext	makeshift	Extinction cell of BA	1793.2			TRUE		Excitat ory					Tatsuya Miyamoto	TM24Amygdala			Warning: 1	1 Warning(s); [109:Source of ID]
8	INAdm	[Hagihara, 2021]	dorsal cluster of medial ITC	1824.1			TRUE	GABA	Inhibit ory					Tatsuya Miyamoto	TM24Amygdala			0	
9	INAvm	[Hagihara, 2021]	ventral cluster of medial ITC	1824.1			TRUE	GABA	Inhibit ory					Tatsuya Miyamoto	TM24Amygdala			0	
10	La_Fear	makeshift	fear part of Lateral neucleus of amygdala	1794.1			TRUE							Tatsuya Miyamoto	TM24Amygdala			Warning: 1	1 Warning(s); [109:Source of ID]
11	CA1_Context	makeshift	CA1 resion for Context Information	1619.1			TRUE							Tatsuya Miyamoto	TM24Amygdala			Warning: 1	1 Warning(s); [109:Source of ID]

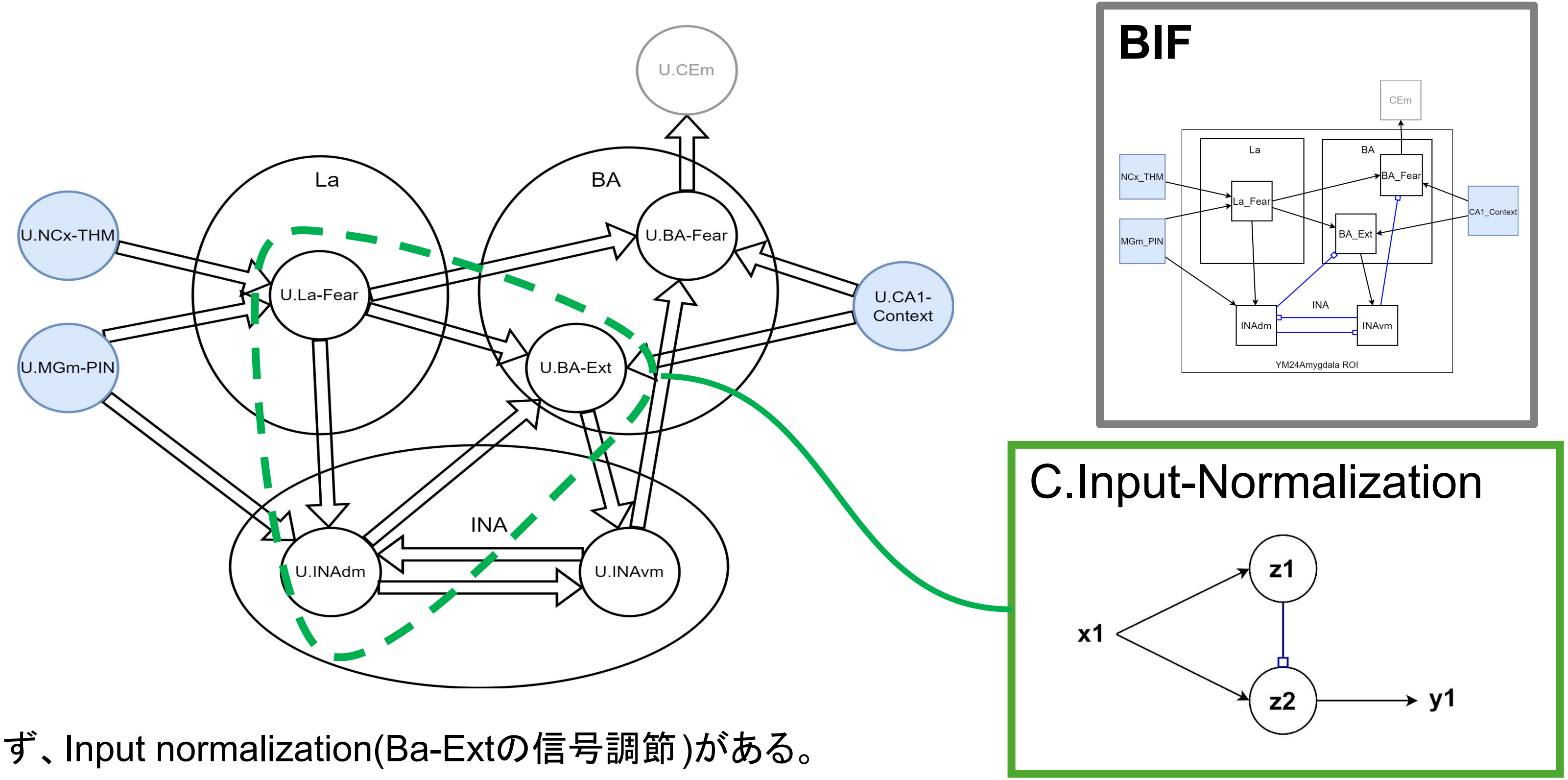
BIF data (Connections)

Connections (14)

1	Sender Circuit ID (sCID)	sCID relation	Notation of sCID in Literature	Receiver Circuit ID (rCID)	rCID relation	Notation of rCID in Literature	Size	Comments	Reference ID	Taxon	Measurement method	Pointers on literature	Pointers on figure	In-depth literature	Doc. Link	Journal names	Litterature type
2	NCx_THM	=		La_Fear	<	La			Pitkänen, 2000	Mouse	Unsurveyed		3		DOC(alt)	Folia morpholo	Review
3	MGm_PIN	=		La_Fear	<	La			Linke, 2000	Mouse	Axonal tracir		7		DOC	Experimental B	Experimental results
4	MGm_PIN	=		INAdm	=				Asede, 2022	Mouse	Unsurveyed		2		DOC	The Journal of Neuroscience	Review
5	La_Fear	<	La	BA_Fear	<	BA			Duvarci, 2014	Mouse	Unsurveyed		2		DOC	Neuron	Review
6	La_Fear	<	La	BA_Ext	<	BA			Duvarci, 2014	Mouse	Unsurveyed		2		DOC	Neuron	Review
7	La_Fear	<	La	INAdm	=				Duvarci, 2014	Mouse	Unsurveyed		2		DOC	Neuron	Review
8	INAdm	=		BA_Ext	=				Hagihara, 2021	Mouse	Optogenetic		4		DOC	Nature	Experimental results
9	INAdm	=		INAvm	=			Measurement method: anterograte tracing	Hagihara, 2021	Mouse	Anterograde		10		DOC	Nature	Experimental results
10	INAvm	=		INAdm	=			Measurement method: anterograte tracing	Hagihara, 2021	Mouse	Retrograde 1		10		DOC	Nature	Experimental results
11	INAvm	=		BA_Fear	=				Hagihara, 2021	Mouse	Optogenetic		4		DOC	Nature	Experimental results
12	CA1_Context	<	CA1	BA_Fear	<	BA			Pitkänen, 2000	Mouse	Unsurveyed		4		DOC(alt)	Folia morpholo	Review
13	CA1_Context	<	CA1	BA_Ext	<	BA			Pitkänen, 2000	Mouse	Unsurveyed		4		DOC(alt)	Folia morpholo	Review
14	BA_Ext	<	BA	INAvm	=				Duvarci, 2014	Mouse	Unsurveyed		2		DOC	Neuron	Review
15	BA_Fear	<	BA	CEm	=	CEm			Duvarci, 2014	Mouse	Unsurveyed		2		DOC	Neuron	Review

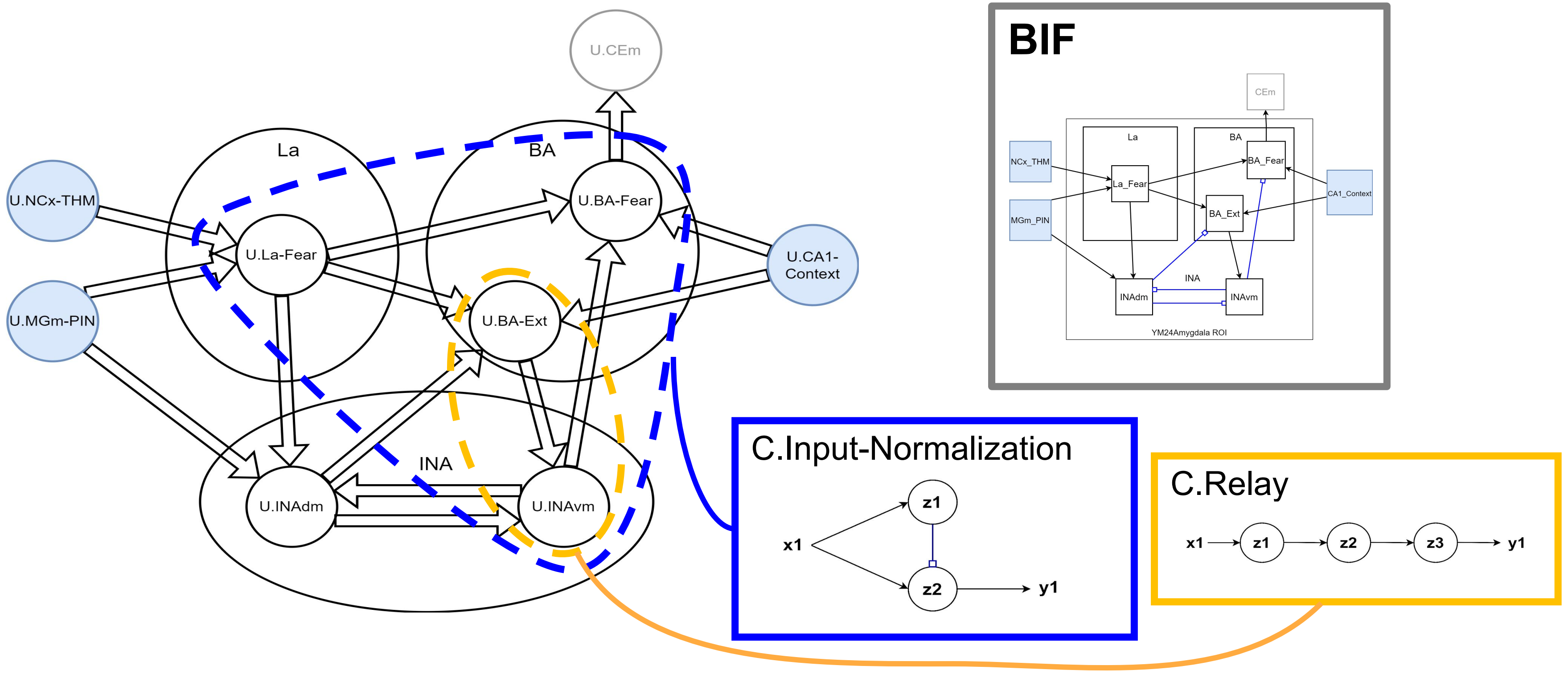
1	Display string per join	Combined string for search	[Reference ID]	Souce region score	Receiver region score	Journal score	Literature type score	Taxon score	Method score	Credibility rating (CR)	Summarized CR	Reviewed CR	Summarized Reviewed CR	Contributor	Project ID	W re
2	La_Fear (03/03) [Pitkänen, 2000];	NCx_THMLa_Fear	[Pitkänen, 2000]	1.000	0.700	0.950	0.800	0.5	0.1	0.027	0.027	0.027	0.027	Tatsuya Miyamoto	TM24Amygdala	
3	La_Fear (32/32) [Linke, 2000];	MGm_PINLa_Fear	[Linke, 2000]	1.000	0.700	0.950	1.000	0.5	0.95	0.316	0.316	0.316	0.316	Tatsuya Miyamoto	TM24Amygdala	
4	INAdm (00/00) [Asede, 2022];	MGm_PININAdm	[Asede, 2022]	1.000	1.000	0.000	0.800	0.5	0.1	0.000	0.000	0.000	0.000	Tatsuya Miyamoto	TM24Amygdala	
5	BA_Fear (02/02) [Duvarci, 2014];	La_FearBA_Fear	[Duvarci, 2014]	0.700	0.700	0.950	0.800	0.5	0.1	0.019	0.019	0.019	0.019	Tatsuya Miyamoto	TM24Amygdala	
6	BA_Ext (02/02) [Duvarci, 2014];	La_FearBA_Ext	[Duvarci, 2014]	0.700	0.700	0.950	0.800	0.5	0.1	0.019	0.019	0.019	0.019	Tatsuya Miyamoto	TM24Amygdala	
7	INAdm (03/03) [Duvarci, 2014];	La_FearINAdm	[Duvarci, 2014]	0.700	1.000	0.950	0.800	0.5	0.1	0.027	0.027	0.027	0.027	Tatsuya Miyamoto	TM24Amygdala	
8	BA_Ext (14/14) [Hagihara, 2021];	INAdmBA_Ext	[Hagihara, 2021]	1.000	1.000	0.950	1.000	0.5	0.3	0.143	0.143	0.143	0.143	Tatsuya Miyamoto	TM24Amygdala	
9	INAvm (29/29) [Hagihara, 2021]Measurement method: anterograte tracing;	INAdmINAvm	[Hagihara, 2021]	1.000	1.000	0.950	1.000	0.5	0.6	0.285	0.285	0.285	0.285	Tatsuya Miyamoto	TM24Amygdala	
10	INAdm (48/48) [Hagihara, 2021]Measurement method: anterograte tracing;	INAvmINAdm	[Hagihara, 2021]	1.000	1.000	0.950	1.000	0.5	1	0.475	0.475	0.475	0.475	Tatsuya Miyamoto	TM24Amygdala	
11	BA_Fear (14/14) [Hagihara, 2021];	INAvmBA_Fear	[Hagihara, 2021]	1.000	1.000	0.950	1.000	0.5	0.3	0.143	0.143	0.143	0.143	Tatsuya Miyamoto	TM24Amygdala	
12	BA_Fear (02/02) [Pitkänen, 2000];	CA1_ContextBA_Fear	[Pitkänen, 2000]	0.700	0.700	0.950	0.800	0.5	0.1	0.019	0.019	0.019	0.019	Tatsuya Miyamoto	TM24Amygdala	
13	BA_Ext (02/02) [Pitkänen, 2000];	CA1_ContextBA_Ext	[Pitkänen, 2000]	0.700	0.700	0.950	0.800	0.5	0.1	0.019	0.019	0.019	0.019	Tatsuya Miyamoto	TM24Amygdala	
14	INAvm (03/03) [Duvarci, 2014];	BA_ExtINAvm	[Duvarci, 2014]	0.700	1.000	0.950	0.800	0.5	0.1	0.027	0.027	0.027	0.027	Tatsuya Miyamoto	TM24Amygdala	
15	CEm (03/03) [Duvarci, 2014];	BA_FearCEm	[Duvarci, 2014]	0.700	1.000	0.950	0.800	0.5	0.1	0.027	0.027	0.027	0.027	Tatsuya Miyamoto	TM24Amygdala	

Exhaustive fitting of Motifs for FRG construction (1/3)



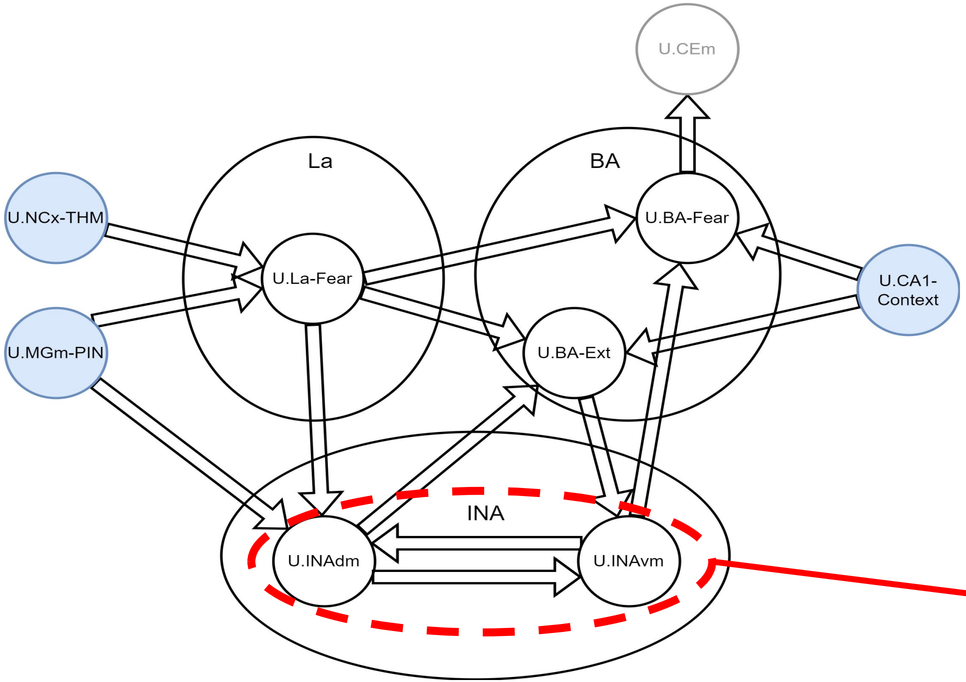
まず、Input normalization(Ba-Extの信号調節)がある。

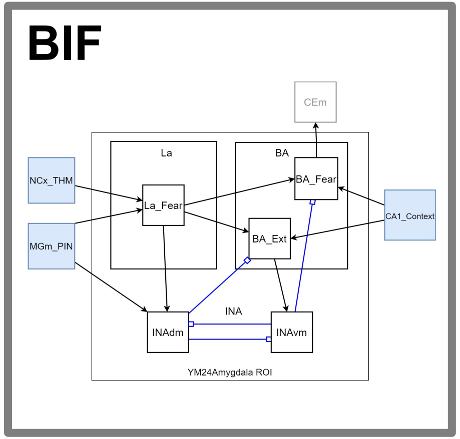
Exhaustive fitting of Motifs for FRG construction (2/3)

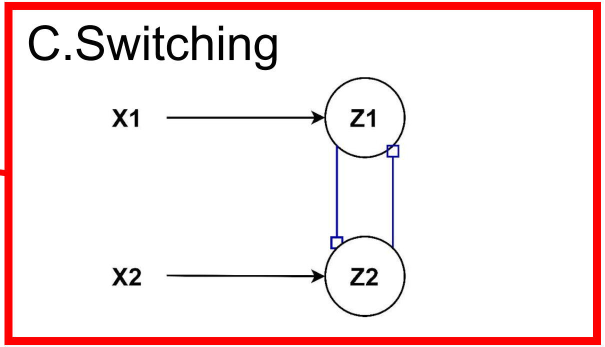


次に、Relayと2つ目のInput-Normalization(Ba_Fearの信号調節)がある。

Exhaustive fitting of Motifs for FRG construction (3/3)

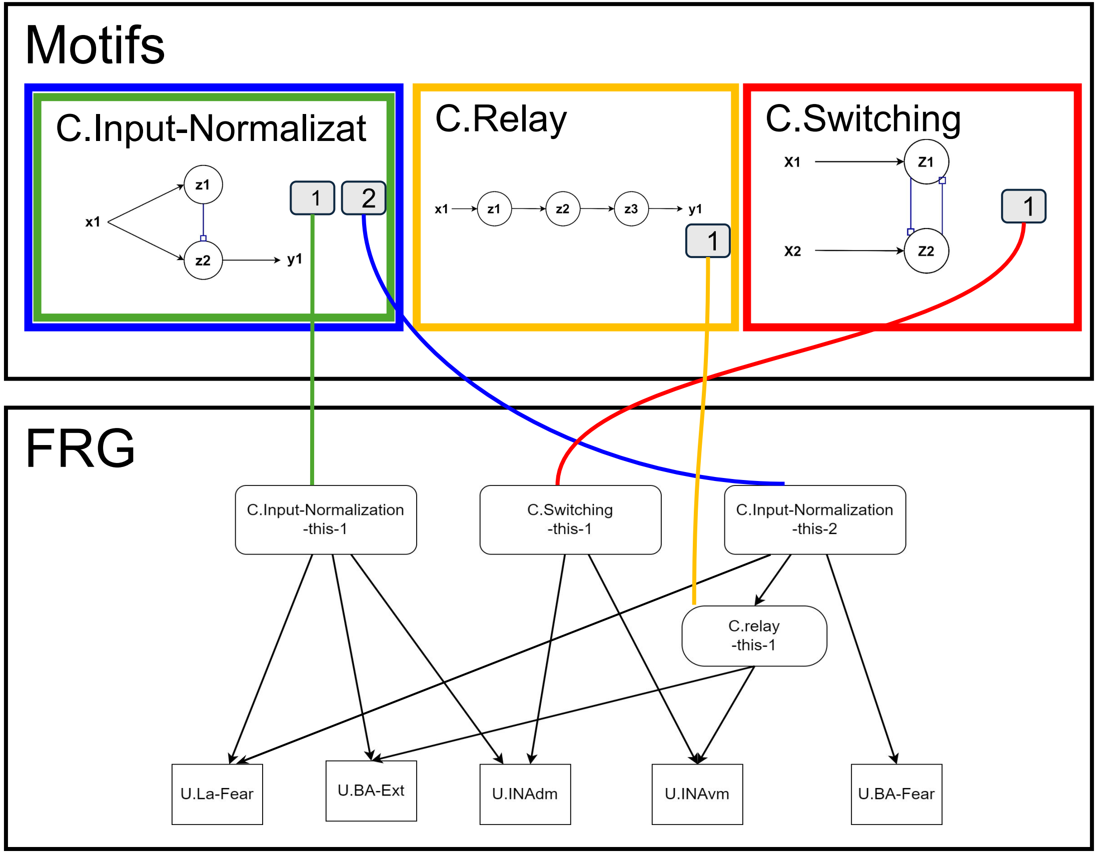






最後にSwitchingがある。

FRG



以上のように、HCDにmotifを当て込むと、
2つの**Input-normalization** と1つの **Switching** (と1つのRelay)が存在する。

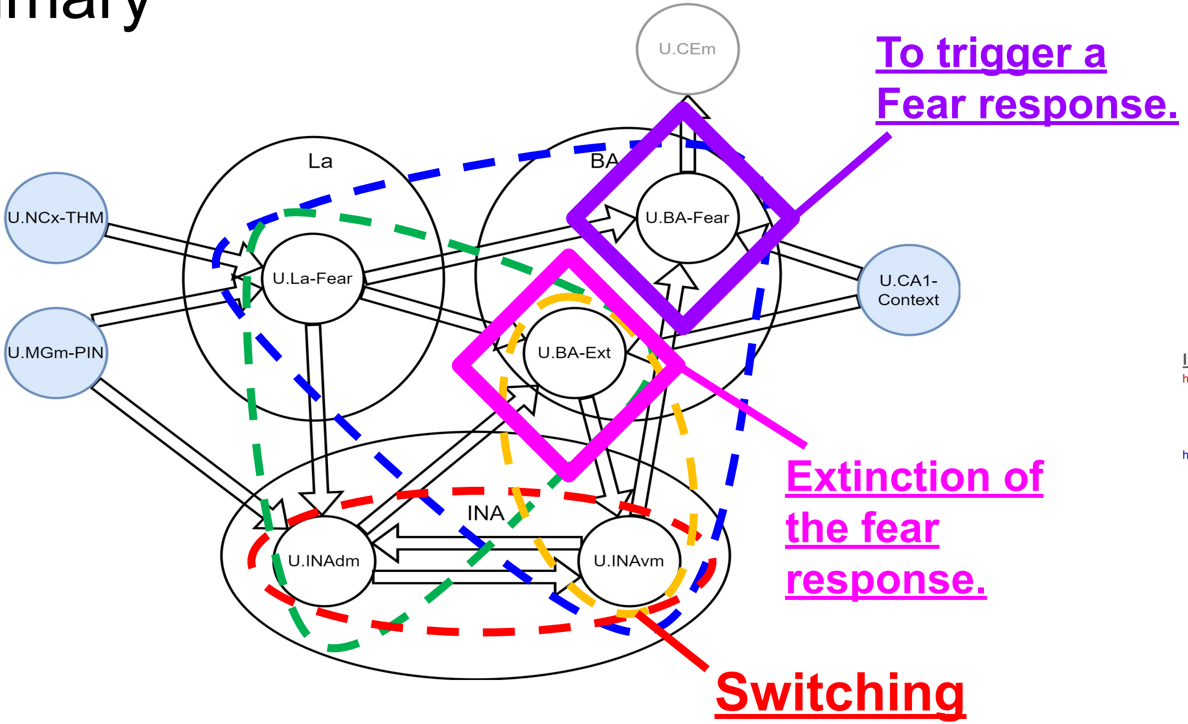
FRG data

Node ID	Subnodes	Circuit ID	Projected Circuits	Projected Circuits Validation	Uniform Circuits	Input Circuits	Output Circuits	[W8] Uniform Circuit Collections	[W8] Merged Input Circuits	[W8] Merged Input Circuit Collections	[W8] Merged Output Circuits	[W8] Merged Output Circuit Collections
C.Input-Normalization-this-2	U.BA-Fear; C.relay-this-1;				BA_Fear; BA_Ext; INAwm	La_Fear; CA1_Context; INAdm	CEm; INAdm	BA_Fear; BA_Ext; INAwm	La_Fear; INAwm; CA1_Context; INAdm; BA_Ext	La_Fear; INAwm; CA1_Context; La_Fear; INAdm; CA1_Context; INAdm; BA_Ext	CEm; INAwm; INAdm; BA_Fear	CEm; INAwm; INAdm; BA_Fear
C.relay-this-1	U.BA-Ext; U.INAwm;				BA_Ext; INAwm	La_Fear; INAdm; CA1_Context	INAdm; BA_Fear	BA_Ext; INAwm	La_Fear; INAdm; CA1_Context; BA_Ext	La_Fear; INAdm; CA1_Context; INAdm; BA_Ext	INAwm; INAdm; BA_Fear	INAwm; INAdm; BA_Fear
C.Input-Normalization-this-1	U.La-Fear; U.BA-Ext; U.INAdm;				La_Fear; BA_Ext; INAdm	NCx_THM; MGm_PIN; CA1_Context; INAwm	BA_Fear; INAwm	La_Fear; BA_Ext; INAdm	NCx_THM; MGm_PIN; La_Fear; INAdm; CA1_Context; INAwm	NCx_THM; MGm_PIN; La_Fear; INAdm; CA1_Context; La_Fear; INAwm; MGm_PIN	BA_Fear; BA_Ext; INAdm; INAwm	BA_Fear; BA_Ext; INAdm; INAwm; BA_Ext; INAwm
C.Switching-this-1	U.INAwm; U.INAdm;				INAwm; INAdm	BA_Ext; La_Fear; MGm_PIN	BA_Fear; BA_Ext	INAwm; INAdm	INAdm; BA_Ext; La_Fear; INAwm; MGm_PIN	INAdm; BA_Ext; La_Fear; INAwm; MGm_PIN	INAdm; BA_Fear; BA_Ext; INAwm	INAdm; BA_Fear; BA_Ext; INAwm
U.La-Fear		La_Fear	BA_Fear; BA_Ext; INAdm;	- - -	La_Fear	NCx_THM; MGm_PIN	BA_Fear; BA_Ext; INAdm	La_Fear			BA_Fear; BA_Ext; INAdm	BA_Fear; BA_Ext; INAdm;
U.INAdm		INAdm	BA_Ext; INAwm;	- -	INAdm	La_Fear; INAwm; MGm_PIN	BA_Ext; INAwm	INAdm			BA_Ext; INAwm	BA_Ext; INAwm;
U.INAwm		INAwm	INAdm; BA_Fear;	- -	INAwm	INAdm; BA_Ext	INAdm; BA_Fear	INAwm			INAdm; BA_Fear	INAdm; BA_Fear;
U.BA-Fear		BA_Fear	CEm;	-	BA_Fear	La_Fear; INAwm; CA1_Context	CEm	BA_Fear			CEm	CEm;
U.BA-Ext		BA_Ext	INAwm;	-	BA_Ext	La_Fear; INAdm; CA1_Context	INAwm	BA_Ext			INAwm	INAwm;
U.CA1-Context		CA1_Context	BA_Fear; BA_Ext;	- -	CA1_Context		BA_Fear; BA_Ext	CA1_Context			BA_Fear; BA_Ext	BA_Fear; BA_Ext;
U.NCx-THM		NCx_THM	La_Fear;	-	NCx_THM		La_Fear	NCx_THM			La_Fear	La_Fear;
U.Mgm-PIN		MGm_PIN	La_Fear; INAdm;	- -	MGm_PIN		La_Fear; INAdm	MGm_PIN			La_Fear; INAdm	La_Fear; INAdm;

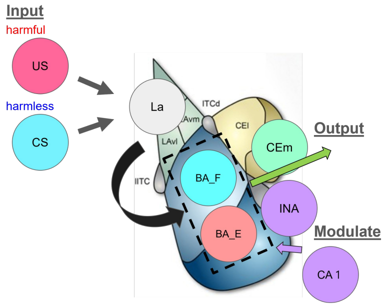
Node ID	Interface	Implementation	Capability Realization by Implementation (LLM)	Capability Realization by Implementation	Implementation of Uniform Circuit	Capability	Ca (LL
C.Input-Normalization-this-2	[BA_Fear, BA_Ext, INAwm] = C.Input-Normalization-this-2 (La_Fear, CA1_Context, INAdm)	[BA_Fear] = U.BA-Fear(La_Fear, INAwm, CA1_Context) [BA_Ext, INAwm] = C.relay-this-1(La_Fear, INAdm, CA1_Context)		Excitatory (U.BA-Fear) and inhibitory (C.relay) signals are downstream of input 1. The inhibitory (C.relay) signal is integrated with the excitatory (U.BA-Fear) signal of input 1, thereby modulating the intensity of the downstream excitatory(U.BA-Fear) signal.		C.Input-Normalization: Adjust the output to suppress excessive excitation.	
C.relay-this-1	[BA_Ext, INAwm] = C.relay-this-1(La_Fear, INAdm, CA1_Context)	[BA_Ext] = U.BA-Ext(La_Fear, INAdm, CA1_Context) [INAwm] = U.INAwm(INAdm, BA_Ext)		The inhibitory(U.INAwm) signal is downstream of input 1 and propagates to the signal further downstream.		C.relay: Information is transmitted directly and forward from one neuron to the next	
C.Input-Normalization-this-1	[La_Fear, BA_Ext, INAdm] = C.Input-Normalization-this-1 (NCx_THM, MGm_PIN, CA1_Context, INAwm)	[La_Fear] = U.La-Fear(NCx_THM, MGm_PIN) [BA_Ext] = U.BA-Ext(La_Fear, INAdm, CA1_Context) [INAdm] = U.INAdm(La_Fear, INAwm, MGm_PIN)		Excitatory (U.BA-Ext) and inhibitory (U.INAdm) signals are downstream of input 1. The inhibitory (U.INAdm) signal is integrated with the excitatory (U.BA-Ext) signal of input 1, thereby modulating the intensity of the downstream excitatory(U.BA-Ext) signal.		C.Input-Normalization: Adjust the output to suppress excessive excitation.	
C.Switching-this-1	[INAwm, INAdm] = C.Switching-this-1(BA_Ext, La_Fear, MGm_PIN)	[INAwm] = U.INAwm(INAdm, BA_Ext) [INAdm] = U.INAdm(La_Fear, INAwm, MGm_PIN)		The downstream of inputs 1 and 2 are inhibitory(U.INAdm, U.INAwm) signals, respectively, and these inhibitory(U.INAdm, U.INAwm) signals are in a mutually inhibitory relationship with each other.		C.Switching: Switch between two inputs.	
U.La-Fear	[La_Fear] = U.La-Fear(NCx_THM, MGm_PIN)	U.LA-Fear = f(U.NCx_THM, U.MGm_PIN)		Recall the representation of input 1, storing input 2 as a teacher signal.	U.LA-Fear = f(U.NCx_THM, U.MGm_PIN)	C.Hebb-Based-Memory-Engram-Formation: Forming memory engrams through synaptic strengthening based on Hebbian principles.	
U.INAdm	[INAdm] = U.INAdm(La_Fear, INAwm, MGm_PIN)	U.INAdm = f(U.La_Fear, U.INAwm, U.MGm_PIN)		Inhibitory neural nucleus (receives input 1, input 2, and inhibits the projection)	U.INAdm = f(U.La_Fear, U.INAwm, U.MGm_PIN)	C.Gabaergic-Neucleus: GABAergic inhibitory neural nucleus, hence it inhibits its projection targets.	
U.INAwm	[INAwm] = U.INAwm(INAdm, BA_Ext)	U.INAwm = f(U.INAdm, U.BA_Ext)		Inhibitory neural nucleus (receives input 1, and inhibits the projection)	U.INAwm = f(U.INAdm, U.BA_Ext)	C.Gabaergic-Neucleus: GABAergic inhibitory neural nucleus, hence it inhibits its projection targets.	
U.BA-Fear	[BA_Fear] = U.BA-Fear(La_Fear, INAwm, CA1_Context)	U.BA_Fear = Recurrent_Neural_Network(U.La_Fear, U.INAwm, U.CA1_Context)		The excitatory inputs of inputs 1 and 2 and the inhibitory input of input 3 are added.	U.BA_Fear = Recurrent_Neural_Network(U.La_Fear, U.INAwm, U.CA1_Context)	C. Memory-Engram-Formation: Forming memory engrams during conditioning processes.	
U.BA-Ext	[BA_Ext] = U.BA-Ext(La_Fear, INAdm, CA1_Context)	U.BA_Ext = Recurrent_Neural_Network(U.La_Fear, U.INAdm, U.CA1_Context)		The representations of inputs 1 and 2 are combined with the representations of input 3 to store and recall the integrated representation	U.BA_Ext = Recurrent_Neural_Network(U.La_Fear, U.INAdm, U.CA1_Context)	C. Memory-Engram-Formation: Forming memory engrams during conditioning processes.	
U.CA1-Context		A			A		
U.NCx-THM		A			A		
U.Mgm-PIN		A			A		

Ask

Summary



Amygdala



・自然に当てはめられたモチーフは 3つ(正確には4つ)だが、この回路のポイントを遠目には表現できている。
(※偏桃体の恐怖条件付け回路：刺激に対して、恐怖反応とその消去が、互いに調整を受けながら生じる)
・今後はモデルシミュレーション等で、検証していく予定。

Dataset Description

3 Dataset Description

Repository location BRA Editorial System (BRAES) https://sites.google.com/wba-initiative.org/braes/data

Object name and versions Please refer to the "Project" sheet in the BRA data for the more detail of data summary.

Table 1: BRA DATA SUMMARY

BRA Data			
Object Name	Template	Including Content(s)	
		BIF	HCD/FRG
YM24Amygdala.bra	*version 2.0*	√	√

Table 2: BRA IMAGE SUMMARY

Graphic Files: BIF Image, HCD Image, FRG Image	
File Type	Object Name
BIF Image	YM24AmygdalaBIF.xml
HCD Image	YM24AmygdalaHCD.xml
FRG Image	YM24AmygdalaFRG.xml

Creation dates 2024-02-08 to 2024-06-30.

Language English.

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Publication date 2024-07-01.